Letters to the Editor.

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Speculation concerning the Positive Electron.

I WRITE hypothetically, and in an interrogative mood except that I scarcely expect a present answer, but it is simpler to state a hypothesis with preposterous dogmatism, in imitation of the unconscious manner of the crank.

According to Larmor's theory the positive and the negative electrons can only differ, or at least must chiefly differ, in one being the mirror-image of the other. One for example might be a concentrated locked right-handed screw-twist in the Ether, while the other would be a left-handed contortion of precisely the same kind, simultaneously and inevitably produced, and connected with its fellow by transferable lines of force. Both would incidentally have to involve also a residual strain or tension, proportional to the square of the twist and inversely as the distance from it.

Needless to say, no positive electron in this sense has yet been discovered. If they exist, why not? Because electrons of both kinds are so extremely mobile, and the forces between them so immense, that they instantly bind themselves together into a compact and exceedingly stable structure, consisting of some hundreds or thousands of each kind; the simplest and lightest of which composite structures we know as the proton or hydrogen nucleus. Short of that grouping, the compound units are either too fully neutralised to be perceived, or else too greedy of each other to exist separately. The proton, for the first time, allows a single electron to be free enough to revolve permanently round the close-packed group without being utterly absorbed and incorporated in its composition.

A number of protons can unite and form the nuclei of other atoms, and in this case several free electrons can remain incompletely assimilated, so as to form a satellite system characteristic of each different element. Such composite nuclei can be shattered by adequate means, but the single nuclei are very stable, and the proton itself has not yet been near disintegration; nor is it clear whether anything detectable could result from its fracture, especially if the fragments were electrically neutral.

But now comes a question, difficult to answer on the mirror-image hypothesis:—Why should only negative electrons occur in the satellite systems? Why should not some atoms have nuclei with a surplus of negative charge, and be attended by positive electrons?

Possibly an answer may be forthcoming from those who either now or hereafter understand the formation of an α-particle, and why it has two positive—and always positive—charges; for it seems to form an essential intermediate ingredient in the building-up process.

But assuming that no answer is forthcoming; are we quite sure that no atoms are of the exceptional variety? Can such a variety exist? It seems a possibility just worthy of contemplation, unless experimental observation already absolutely negatives it. Photo-electric evidence is strong; the Zeeman effect appears conclusive. But is it final? It demonstrates clearly enough that the radiating particle has an electro-chemical equivalent of the order 10^7, and is therefore an electron of some kind, but is it conclusive about the sign in all cases? Perhaps it is: but there is no harm in reconsidering a conclusion occasionally, even if the already accepted answer turns out quite indubitable.

If all radiation is from the negative electron only, that curious fact would seem to point to some striking qualitative difference between the negative and the hypothetical positive electron: a difference which on Larmor's theory of the Ether is difficult to grant, though it may have to be granted. It is owing to this difficulty that there has arisen the otherwise attractive idea of a positive electron so intensely concentrated as to be about 1/1800th of the linear dimension of the negative electron, and therefore to possess incomparably greater inertia. This may be the right way out of the difficulty, but it requires proof.

If, pending proof, we try to work with a mirror-image pair of electrons, can we anyhow account for the apparent fact that atoms have only negative satellites? Perhaps thus:—Consider a crowd of new-born electrons, both positive and negative. If, among the manifold chances of structural packing, something less than half of the atomic nuclei formed were of the kind with positive satellites, while the other approximate half were of the negative satellite variety, the two classes would speedily combine with a violence inappropriate to anything that can be called molecular combination. They would thereby form the tight-packed and stable nuclei of heavier atoms, until the complexity was great enough to result in instability. That may be how the heavier atoms were formed. If the packing took place by chance, there might be a small surplus of one variety in excess.

The combination of nuclei would only cease when they were protected by a screen of similar electrons; their sign might be + or might be − but could not be both. In other words the resulting atoms could not be of opposite varieties; the satellites of the surplus variety must be all of one sign, or the atoms would combine with each other and form a new substance. Thus we could get the outlying satellites of one sign, either in every case or in so vast a preponderance of cases that no exceptions are as yet manifest. In the nascent stages there might be a random distribution of the two varieties, in numbers nearly equal but not accurately equal, like the male and female of a population; then most of them would mate and constitute higher nuclei, while the variety which happened to be in the majority would remain as it was, and become conspicuous. The number mated might be a hundred times greater than the number of outstanding single ones and yet these last would be what we know as the atoms of the elements familiar to-day. It is plain that the number of protons embedded in the nuclei of all the atoms must be in excess of the number of atoms themselves. The atoms themselves represent the surplus, the excess kind that could find no partners. The number of protons embedded in atomic nuclei are $\frac{(1+2+3+\ldots+92)}{92}$ times the number of known atoms, say 46 times as numerous.

Some fallacy here: for the elements are not all equally plentiful. But the middle ones are on the whole the most plentiful, and the statement may pass as a rough approximation.

Directly a positive variety of atom gets loose, it will combine with the nearest negative variety accessible, and push it a step or two up the series. In that way heavier elements may still occasionally be born. The free life-time of the less plentiful variety would be too brief for ordinary detection;

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but now that shattering of nuclei is possible, and now that rapid means of detection are feasible, there is something to look for. The formation of strange substances and unusual combinations may be expected, and the composite nature even of the proton may yet be demonstrated by the emission of something fractional of extreme instability. Does not the atomic bombardment of aluminium already yield particles of extra long range?

I make no apology for this surmise. Speculation as a temporary working hypothesis is sometimes suggestive of further experiment, and that is its sole justification. If the tendency of the discussion is to uphold the greater simplicity of the extra-small and extra-massive indivisible positive particle, well and good; but that would rather close the door on one line of experiment, and it is not well to abandon the mirror-image idea prematurely. The proton *may* be an indivisible ultimate unit; but that seems unlikely, and we have learnt not to negative the possibility of ascertainable structure lightly. It seems barely credible, now, that it was as an indivisible ultimate unit that we used to regard the atom!

The hypothesis that a proton is built up of positive and negative but otherwise identical electrons may yield a hydrogen nucleus too bulky for the facts, and may otherwise have to be rejected, but the idea at least leaves the door open to the extraordinarily brilliant experimental physicists of to-day, and hence as long as possible may be tentatively and provisionally encouraged. OLIVER LODGE.

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The Measurement of Intervals.

I CANNOT resist Mr. Cunningham's invitation in his review of my Romanes Lecture (NATURE, Oct. 28, p. 568) to justify more precisely the transition from the picture of world-history as a tangle of world-lines to the scheme of intervals filling a continuum of space-time and demanding non-Euclidean geometry. "Prof. Eddington seems to contemplate as 'measurable' the intervals between pairs of points in this continuum which do not correspond to events in the history of any particle or electron in the material universe. But we wish to ask him how these intervals are in practice to be measured." Mr. Cunningham's point is that the picture which we have to dissect is the *actual* history of the world, and we are not allowed to alter it—to introduce measurements which never were made, or to introduce physically recognisable events at points where nothing actually happened. I accept this limitation. He admits, however, that all measurements that have ever been made are contained in the picture, and, I might add, all measurements that ever will be made. Thus we have a large number of measured intervals available for discussion; and I think that Mr. Cunningham, like myself, is convinced that the geometry which these measured intervals obey is not exactly Euclidean but is given correctly by Einstein. When once this geometry is determined we proceed to fill all space-time with *calculated* points and intervals; just as we ordinarily fill all space with calculated points and distances after first determining the geometry by means of a few distances actually measured and a few points actually perceptible. Only a small number of the calculated points and intervals correspond to events and measurements in the historical picture; but whenever there is a measured value it will agree with the calculated value.

As regards the status in physics of this scheme of calculated points and intervals, it does not seem necessary to make any hypothesis; indeed, I scarcely know what hypothesis could be made about it. At the back of my mind I vaguely suppose that it is "closely descriptive" of an underlying relation-structure of the actual world; but whatever that means (if it means anything) it is too indefinite to use as an hypothesis. It is sufficient that we find it profitable to talk about this scheme. But at least its status is in no way inferior to the picture of tangled world-lines which Mr. Cunningham finds it convenient to start from. Material particles and events outside us are not directly observed: they are inferred from the fields (inertial and electromagnetic) which affect our bodies. But the field itself is not directly observed; it produces disturbances in the bundle of world-lines called a man. Inside the man the disturbance passes from field to matter and matter to field in endless cycle. Who shall say at what phase of the cycle it takes the final plunge into the realm of consciousness and actuality? Rightly or wrongly the method of science has always been to generalise from observation—to talk about a world which includes all that has been observed and a great deal which has not been observed. The astronomer does not make the *hypothesis* that the moon exists when nobody is observing it; but he finds it profitable to talk about a conceptual picture which contains a continuously existing moon. The scheme of calculated points and intervals (æther, or field) or of tangled world-lines (matter), or preferably both together, forms the world which the physicist finds it profitable to discuss; he can scarcely attribute more virtue than that to any world without wandering into metaphysics.

I must dissent entirely from Mr. Cunningham's statement that "any geometrical system whatever may be used for the purpose of attaching intervals." Clearly if a wrong geometrical system is used, the *measured* intervals will expose it by their disagreement. But Mr. Cunningham in this passage seems to use the word interval as though it had no fixed meaning and he could make it mean what he liked. If I recollect rightly, I originally introduced the name "interval," preferring it to the name "line-element" then current, which seemed unsuitable for a physical quantity as savouring too much of pure mathematics. I intended "interval" to mean a definite physical quantity—quite as definite as "energy," for example; and I desire to guard its meaning jealously. If the meaning of "energy" can be altered at pleasure, it is easy to upset the law of conservation of energy; and similarly by treating "interval" and "length" as words meaning nothing in particular, Mr. Cunningham has no difficulty in disposing of my contention that the world is not a Euclidean or flat world.

It will be seen that Mr. Cunningham and I are essentially in agreement that the merit of the Einstein scheme of intervals is its simplicity—"profitable to talk about"—rather than some kind of metaphysical significance. He regards it as selected from many other possible schemes because it gives a simple representation of the motion of particles and light-rays. That is a quite good enough reason for selecting it, but it must be borne in mind that it is not the historical reason for choosing it. The fact that it describes the exact motion of Mercury in a particularly simple way was only discovered after the whole scheme had been completed. The interest of Einstein's scheme is that there is, not one reason, but several reasons for selecting it. Not the least important of these reasons is that the scheme expresses the geometry of the world—in the sense in which the

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